

**CRITERIA FOR EVALUATING THE EFFICIENCY OF INTELLIGENT
PASSENGER FLOW MANAGEMENT ON METROPOLITAN
ESCALATORS.**

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Abstract. This thesis examines the problem of evaluating the efficiency of AI-based intelligent passenger flow management systems on metropolitan escalators. The aim of the study is to develop a comprehensive evaluation criteria system covering technical, operational, economic, and social-safety dimensions. As a result of the analysis, a four-group criteria system and the concept of an integral efficiency index are proposed.

Keywords: artificial intelligence, intelligent management, efficiency evaluation, criteria system, metropolitan, escalator, integral index.

The burden on urban transport infrastructure, particularly on metropolitan systems, is growing year by year in modern large cities. The passenger flow of the Tashkent Metropolitan has increased significantly in recent years, with tens of thousands of passengers served daily at the system's busiest stations [1]. Under these conditions, the deployment of intelligent management systems based on artificial intelligence and computer vision technologies has become an urgent task for reducing congestion, queuing, and accident risks on escalators. However, before such systems can be implemented in practice, it is necessary to evaluate their efficiency through objective, scientifically grounded criteria — otherwise, the rational allocation of investment and the demonstration of the system's practical usefulness become considerably more difficult.

The Concept of Efficiency and Its Multidimensional Nature

The concept of “efficiency” for an intelligent management system is multidimensional and complex in nature. It cannot be limited solely to technical

indicators — such as object detection accuracy or system speed. Efficiency should instead be regarded as a complex category encompassing technical, operational, economic, and social-safety dimensions. Accordingly, evaluating such a system requires a multi-criteria evaluation framework rather than a single-dimensional approach.

Technical-Algorithmic Criteria

The first group — technical-algorithmic criteria — includes: detection accuracy (measured via the mAP indicator), processing speed (FPS), the rate of false positive and false negative results, and the overall latency indicator in real-time mode. A comparative analysis of various YOLO models in terms of accuracy and speed shows that these two indicators are typically inversely related, which is why evaluating them through a balanced composite index, rather than in isolation, yields more accurate results [2, 3].

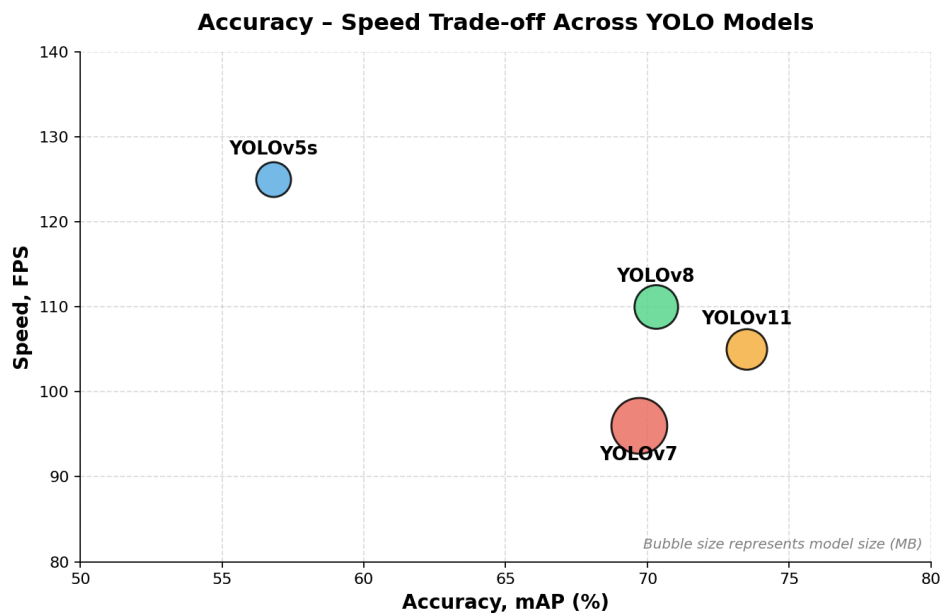


Figure 1. Accuracy–speed trade-off across YOLO models

Operational Criteria

The second group — operational criteria — includes the system's throughput (the number of passengers processed simultaneously), its stability under varying lighting, crowd density, and weather conditions, as well as the system's uptime coefficient. In practice, distributed deep learning systems have been reported to achieve 94–99% accuracy in real-time conditions; however, this indicator should be re-verified

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not only under laboratory conditions but also across various operational environments [4].

Economic Criteria

The third group — economic criteria — covers the costs of implementing and operating the system, the socio-economic losses avoided through reduced accident rates, and the return-on-investment (ROI) period. Evaluating economic efficiency requires accounting not only for direct costs but also for indirect costs related to maintenance, model retraining, and infrastructure upgrades.

Social-Safety Criteria

The fourth group — social-safety criteria — includes the rate of reduction in accidents [5], the level of passenger trust and satisfaction with the system, and compliance with personal data protection requirements. Preserving privacy is particularly important in video-surveillance-based systems, which is why skeleton-based pose estimation approaches are increasingly favored [6].

The four criteria groups discussed above are summarized in Table 1.

Criteria Group	Key Indicators	Unit of Measurement
Technical-Algorithmic	Accuracy (mAP), processing speed (FPS), false positive/negative rate, latency	%, FPS, %, ms
Operational	Throughput, stability across conditions, uptime coefficient	persons/hour, %, %
Economic	Implementation and operating cost, loss reduction, return on investment (ROI)	currency, currency, months/years
Social-Safety	Incident reduction, user trust, compliance with personal data protection	%, score, compliance level

Table 1. Efficiency evaluation criteria for the intelligent management system

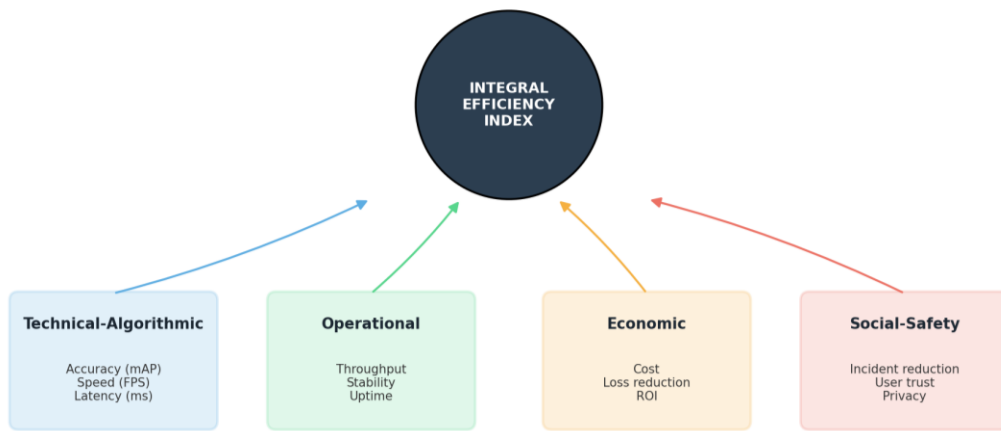


Figure 2. Conceptual framework of the efficiency evaluation criteria system

Integral Evaluation Approach

Based on the four criteria groups outlined above, an integral efficiency index can be formulated. In this framework, each criteria group carries a specific weight coefficient, which can be determined through expert evaluation or statistical analysis methods. In general form, the integral index is expressed by the following formula:

$$R_{integral} = w_1C_{tech} + w_2C_{oper} + w_3C_{econ} + w_4C_{social}$$

where C_{tech} , C_{oper} , C_{econ} , C_{social} are the normalized values of the technical, operational, economic, and social-safety criteria groups, respectively, and w_1 – w_4 are their weight coefficients ($w_1+w_2+w_3+w_4=1$). Sample weight coefficients are presented in Table 2.

Criteria Group	Proposed Weight (%)	Justification
Technical-Algorithmic	30%	Determines the system's core functional reliability
Operational	25%	Ensures stable performance under real-world conditions

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Criteria Group	Proposed Weight (%)	Justification
Economic	20%	Reflects the project's financial feasibility
Social-Safety	25%	Protects the interests of end users and society

Table 2. Sample weight coefficients for computing the integral efficiency index

Such an integral approach enables an objective comparison of technological solutions implemented across different stations, as well as the identification of directions for system improvement.

Methodological Foundations

One of the key issues in the practical application of these criteria is standardizing the methodology used to measure them. In particular, the safety requirements set out in international standards such as EN 115-1:2017 and ISO 8102-6:2019 should be incorporated as a reference point within the evaluation criteria system, and accuracy and speed indicators should be tested separately under both laboratory (benchmark dataset) and real operational conditions [7, 8].

Conclusion

In conclusion, evaluating the efficiency of intelligent passenger flow management systems on metropolitan escalators is a complex process that integrates technical, operational, economic, and social-safety dimensions. The proposed four-group criteria system and integral evaluation approach are planned to be tested in practice in future research and verified using real data from the Tashkent Metropolitan. This, in turn, will contribute to improving the scientifically grounded decision-making process for the practical implementation of such systems.

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